LIMITED CIRCULATION

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Microclimate studies on a mid-Wales hill slope

by Perry Roe

SUMMARY

Documentated microclimatic studies are few and far between in Wales, particularly those relating to sloping ground. The most notable work has been carried out by Taylor (1958) on Pen Dinas hill near Aberystwyth. Other studies of local climate have been made by Smith (1950, 1952), Oliver (1960, 1964) and Harrison (1973).

There is, therefore, a need to gather more information on slope microclimate, firstly to highlight the potential for agricultural productivity and secondly to provide input to the Agricultural Land Classification (ALC) scheme work currently being undertaken in ADAS.

This paper presents the results of an intense 4 week study of temperatures and winds on a westerly facing hill slope at Trawsgoed, near Aberystwyth during 1984.

1. Introduction

The microclimate of a slope is determined by several factors, namely: steepness, aspect, vegetation, soils and proximity relative to neighbouring topographic influences. In particular the radiation budgets are modified which in turn affect the temperature regime of the lower atmosphere and soil layers. In addition localised air circulations tend to develop when there are weak regional pressure gradients.

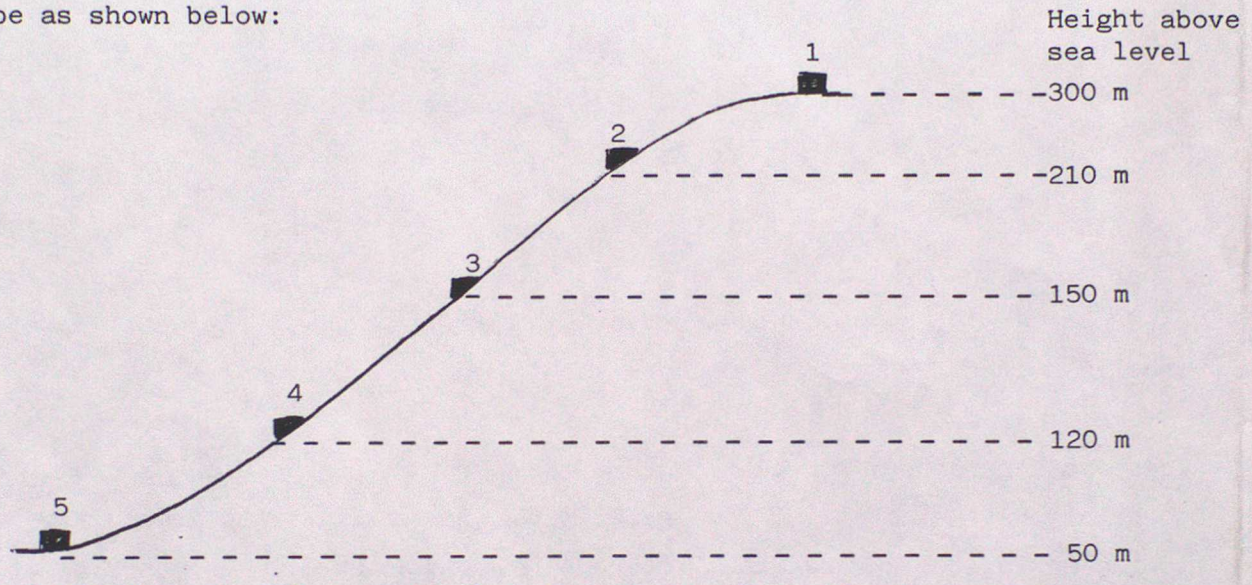
The present study neither considers the individual effects of these factors on slope microclimate nor attempts to relate these results to those carried out piecemeal by other workers. Rather it considers the interaction of all these influences as they act upon air, soil temperatures and 2 m winds at one chosen slope.

It is expected that models of the processes occurring over slopes will eventually enable slope microclimate to be determined from very few inputs (steepness, aspect etc). It is hoped that the information presented here will allow 'fine tuning' of these models.

2. Site details and instrumentation

The site chosen for the study was the west-facing valley side of the River Ystwyth, 9 miles south-east of Aberystwyth. The mid-slope gradient is approximately 1 in 3 and land use was rough grazing except for the valley floor and lower slope where there was permanent pasture.

Five mini-met sites were established in 1 m square enclosures on a transect following the slope as shown below:



The instrumentation at each site is described in the Appendix.

Readings were taken each day as near to 0900 GMT as possible. This involved driving to site 1 to take readings at sites 1, 2 and 3 and then driving to site 4 to take readings at sites 4 and 5. There was usually about ¾ hr delay between taking readings at sites 1 and 5. Recordings were made over the period March 20-30, 1984 and April 10-23, 1984 inclusive.

3. Results and discussion

Site 5, the valley floor, was chosen as the base station for the intercomparison of sites.

3.1 Air Temperature

a) Maximum

Figure 1a shows the daily differences - mean and standard deviation - for maximum temperature throughout the study period. The valley floor (50m) maximum temperature was on average 1.9°C warmer than the hilltop (300m) - a lapse rate of 0.8°C per 100m. Differences were greatest on warm sunny days, reaching a maximum of 3.2°C and least on dull, overcast days with rain and/or strong winds.

Sites 2, 3 and 4 were often cooler than the valley floor (although not always so) and the mid-slope (3) was slightly warmer than the lower slope. The differences tended to reduce in line with the decreasing altitudinal difference.

b) Minimum

Figure 1b shows the daily differences - mean and standard deviation - for minimum temperature throughout the study period. Radiation nights were considered separately to other nights to illustrate the temperature drop associated with katabatic pooling of cold air on such nights. Sites 1 to 4 were all warmer than the valley bottom on radiation nights by amounts ranging from 1.4 to 2.6°C on average. Differences exceeded 3°C on several days and on one night site 2 was 5.4°C warmer than the valley floor 160m below. The reason why site 2 should be warmer on radiation nights can be explained in terms of the "thermal belt" described by Geiger (1980, P431). This is an area of comparatively warmer temperatures lying above the inversion.

On "other nights", the valley bottom site was warmer by up to 0.8°C on average; on one occasion the mid-slope site was 1.4°C colder than the valley bottom.

c. Comparison of screen and 'cocoa-tin' temperatures at site 1

The comparison is shown in Table 1

Table 1

Comparison of screen(s) and cocoa-tin (c) air temperatures at hill-top site (all nights)

	DIFFERENCE S-C	
	MEAN	STAN.DEV.
MAXIMUM TEMPERATURE	-1.31	0.53
MINIMUM TEMPERATURE	0.38	0.29

These figures clearly show that the 'cocoa-tin' is more suited to measurements of minimum temperatures than it is for the measurement of maximum temperatures.

3.2 Grass minimum temperature

The pattern of differences noted for minimum temperatures is repeated for grass minimum temperatures (see Figure 2) ie. sites on the valley side are warmer than the valley bottom on radiation nights and vice-versa on other nights. Perhaps worthy of note is the fact that on radiation nights the difference between grass minimum at sites 3 and 4 compared to site 5 is accentuated compared with the corresponding air minima differences, but the opposite is true at site 2 (ie grass minimum difference is less than air minimum). The reason for this is not entirely clear but is possibly associated with a shallow downward flow of air below 'cocoa-tin' level as noted by Bird (1980). The difference is unlikely to be attributable to differences in soil texture - which are very similar at each site - or land use.

3.3 Soil temperature

The day-to-day soil temperature fluctuations are shown in Figure 3 together with the means and standard deviations of the differences between sites. The following are the salient features of the graphs:-

i. the temperature lift experienced at the valley site(s) over the other sites is gradually reduced as one moves down the valley side. Indeed the lower slope consistently experienced higher 30 cm temperatures than the valley floor, while the hilltop was on average 0.8°C cooler.

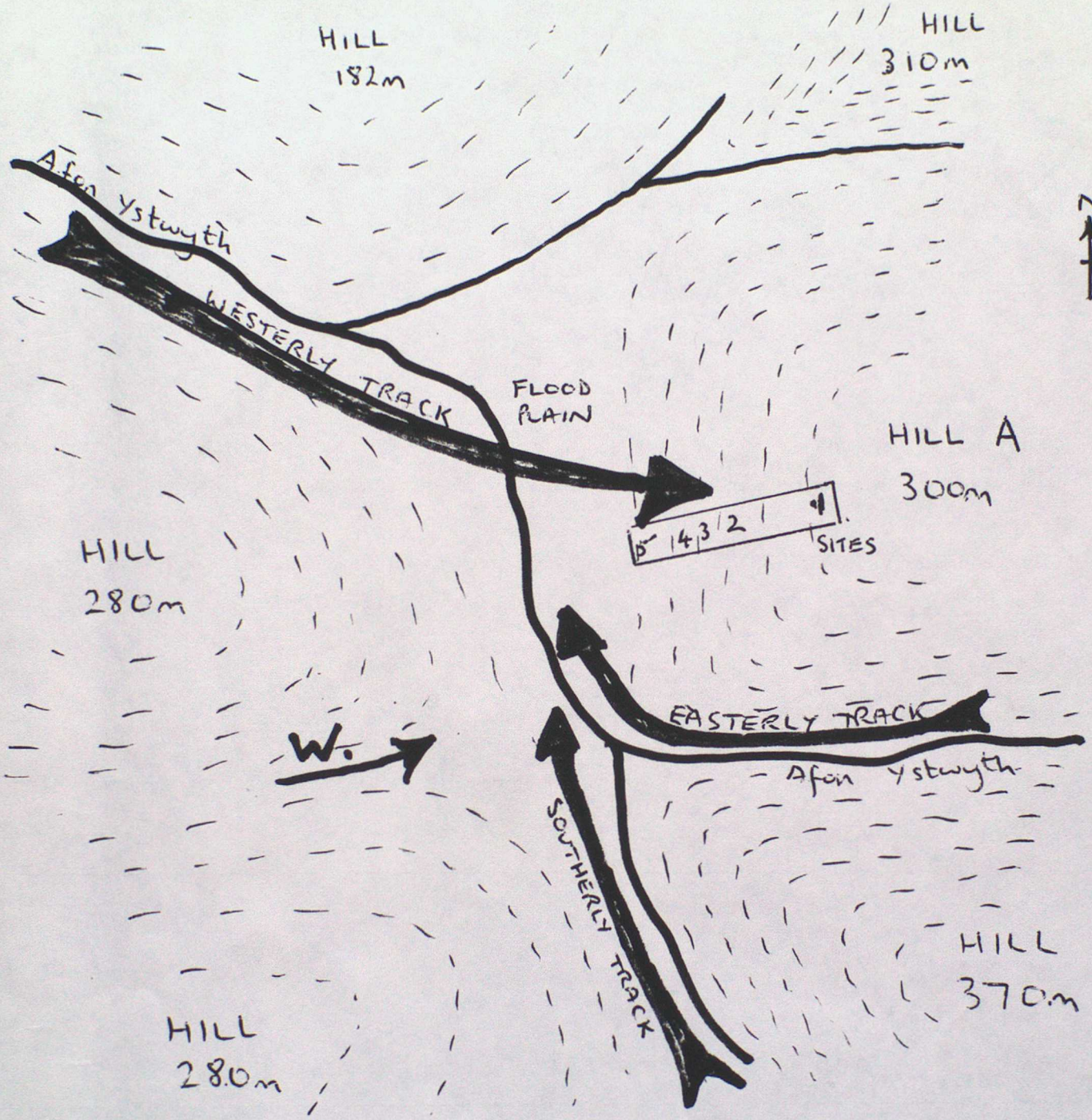
ii. 10 cm maximum soil temperatures showed greater variability along the slope profile than did the 10 cm minimum soil temperatures. On occasions the upslope sites experienced higher maxima amd minima than lower down the slope.

iii. 5 cm soil temperatures showed the greatest day-to-day fluctuations. Temperatures upslope were consistently lower than in the valley bottom, by as much as 2.4°C at the hilltop.

3.4 2 metre run-of-wind

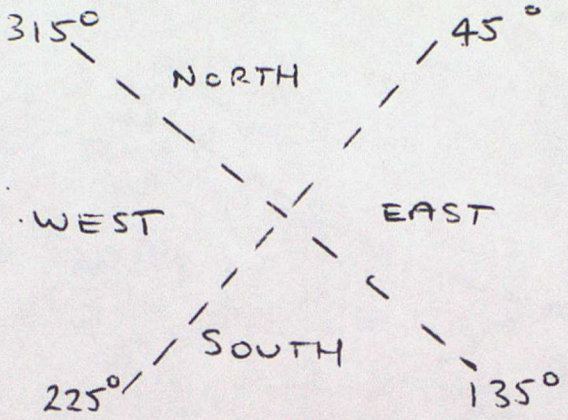
The wind regime of the study slope is very much effected by the orientation of local valleys and associated 'funnelling' or 'channelling' effects described by Wippermann (1984)

A very simple sketch of the topography is shown below.



Winds with a westerly component are prone to funnelling along the Ystwyth Valley where they will tend to blow directly up the study slope. Southerly winds are also funnelled as shown and tend to blow obliquely across the slope in addition to over the hilltops. Easterly winds will funnel along the Ystwyth Valley as shown but will then flow along and away from the slope up; in addition easterlies will blow over the top of hill A and down the slope.

In order to analyse the windspeeds some account of direction must be made because of the funnelling effects described above. In order to do this 4 categories of wind direction are considered, the limits of which are shown below:-



Hourly wind records from the SAWS site, one-third of a mile north of the study slope were used to determine each days predominant direction.

The wind analysis for 23 days observations are shown in Table 2; each site is expressed as a proportion of the corresponding value at the valley (reference) site.

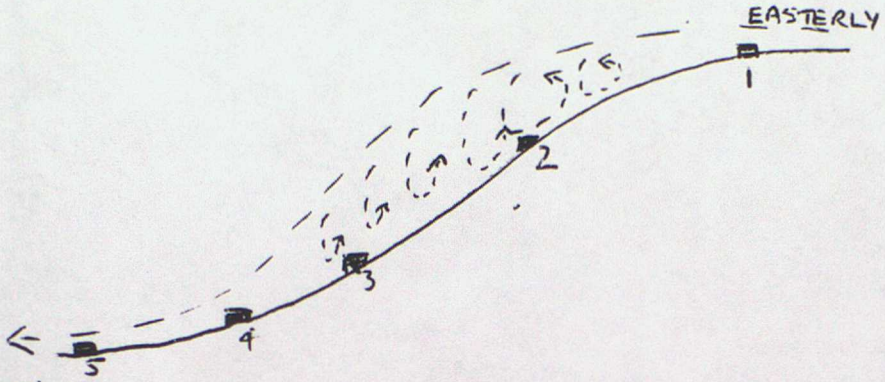
TABLE 2

Comparison of daily 2 m run-of-wind at each site

Direction	Number of occasions	Hill-top 1÷5	Upper slope 2÷5	Mid slope 3÷5	Lower slope 4÷5
West	10	1.82	1.39	1.40	1.03
South	9	1.72	1.19	1.10	0.75
East	4	2.33	0.65	0.81	0.74
North	0		No occasions		
All	23	1.85	1.10	1.12	0.85
range		1.49-3.03	0.43-1.67	0.55-2.08	0.63-1.18

Only tentative conclusions can be drawn from such a small sample but despite this, Table 2 indicates quite clearly the acceleration of wind up the slope for winds from a W or S direction: winds at site 1 are a factor of 2 higher than those at the base of the slope and valley bottom. For E winds the hill-top site is clearly very exposed and the slope itself very sheltered; there is evidence to suggest that winds accelerate down the slope as indicated by higher windspeeds in the valley bottom. Wind might also 'leak' round the sides of the hills as well.

Site 2 is in an area of comparatively calm winds while site 3 lies in the path of winds returning to follow the contours of the slope as shown in the sketch below.



4. Conclusions

The following observations can be drawn from this work:-

i Maximum air temperatures were generally higher in the valley bottom than on the valley sides, but not always. Differences were greatest on warm, sunny days reaching a value of 3.2°C on one occasion. An average lapse rate between hill-top and valley bottom of 0.8°C per 100 m was measured.

ii. Minimum air temperatures on radiation nights were as much as 5°C colder on the valley floor than on the valley side. Differences on non-radiation nights were much less, and were reversed with the valley bottom being the warmest site. A similar pattern was noted for grass minimum temperatures.

iii Soil temperatures at depths of 10 and 30 cm were frequently higher on the mid and lower slope than they were in the valley bottom. 5cm soil temperatures were always lower on the slope than they were in the valley bottom.

iv. The wind regime of the slope was influenced to a great degree by funnelling in local valleys. Winds from the south or west blowing up the slope might double in strength in reaching the hill-top whereas winds blowing from the east were strongest at site 1 but much weaker lower down the slope and in the valley bottom.

5. Acknowledgments

The help and encouragement provided by Dr John Starr, Agro-meteorological Officer for Wales, throughout this study is gratefully acknowledged. The EHF Farm Director, Trawsgoed, kindly permitted meteorological sites to be erected on his farm. The comments of Dr Hough, Harrogate, are appreciated.

7. REFERENCES

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Any comments or suggestions on this paper should be sent to the author.

KEY WORDS

Slope/Microclimate

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APPENDIX

Instrumentation at mini met. sites

All 5 sites had maximum and minimum thermometers in 'cocoa-tin'mounts at approximately 1 m above ground; grass min. thermometer and 30 cm soil thermometer and 2 m cup counter anemometer. In addition there were the following items:

Site 1

Stevenson screen with maximum and minimum thermometers, thermohygrograph

10 cm max/min soil thermometer) in bare plot on the slope surface
5 cm soil thermometer)

Sites 2 and 3

10 cm max/min soil thermometer) in bare plot on the slope surface
5 cm soil thermometer)

Site 5

Stevenson screen 20 cm above ground (laid on breeze blocks) with thermohygrograph

10 cm max/min soil thermometer) in bare plot on the slope surface.
5 cm soil thermometer)

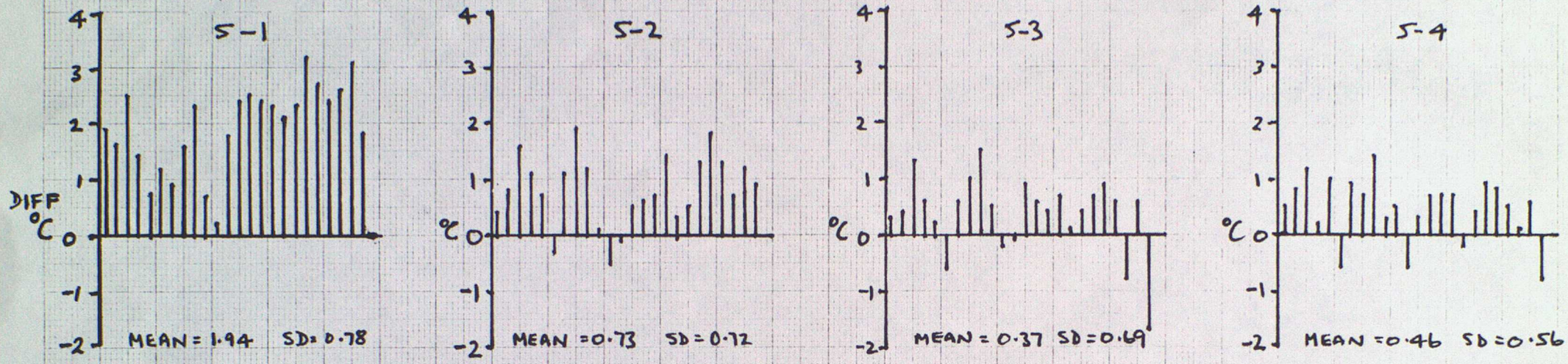
Reference site: SAWS meteorological enclosure (NGR: 2674 2736), approx. one-third of a mile distant from site 5 along valley floor was used for reference to anemograph and temperature records on occasions.

DAILY AIR TEMPERATURE DIFFERENCES BETWEEN VALLEY (REFERENCE) SITE AND OTHER SITES

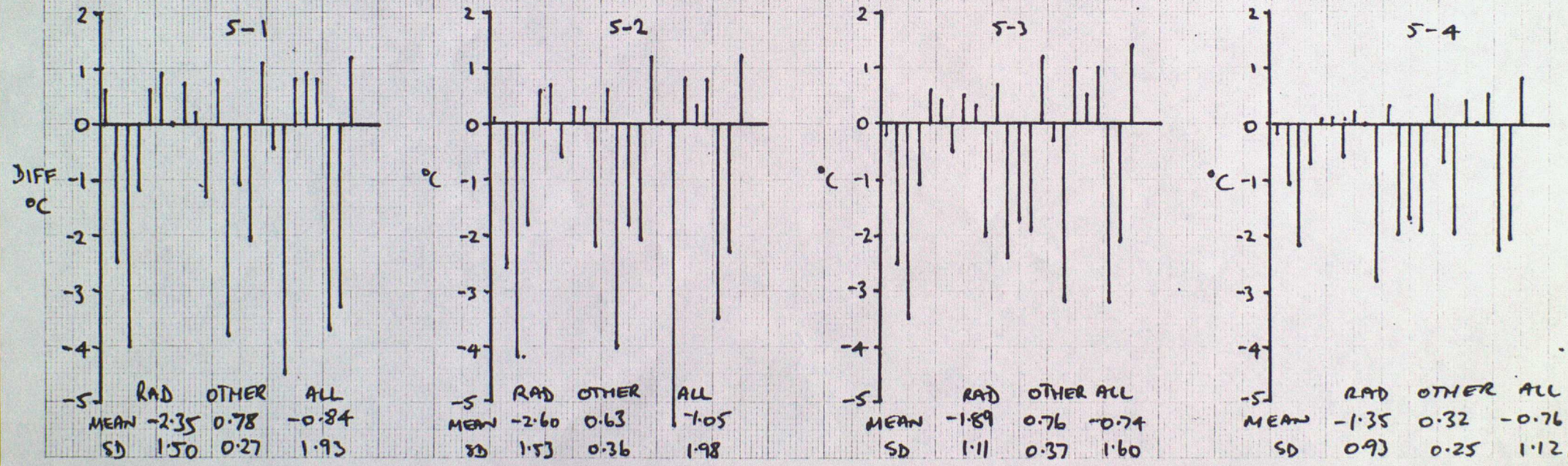
1 HILL SITE 2 UPPER SLOPE 3 MID SLOPE 4 LOWER SLOPE
5 VALLEY FLOOR

1a MAXIMUM

ABOVE AXIS : VALLEY SITE WARMER



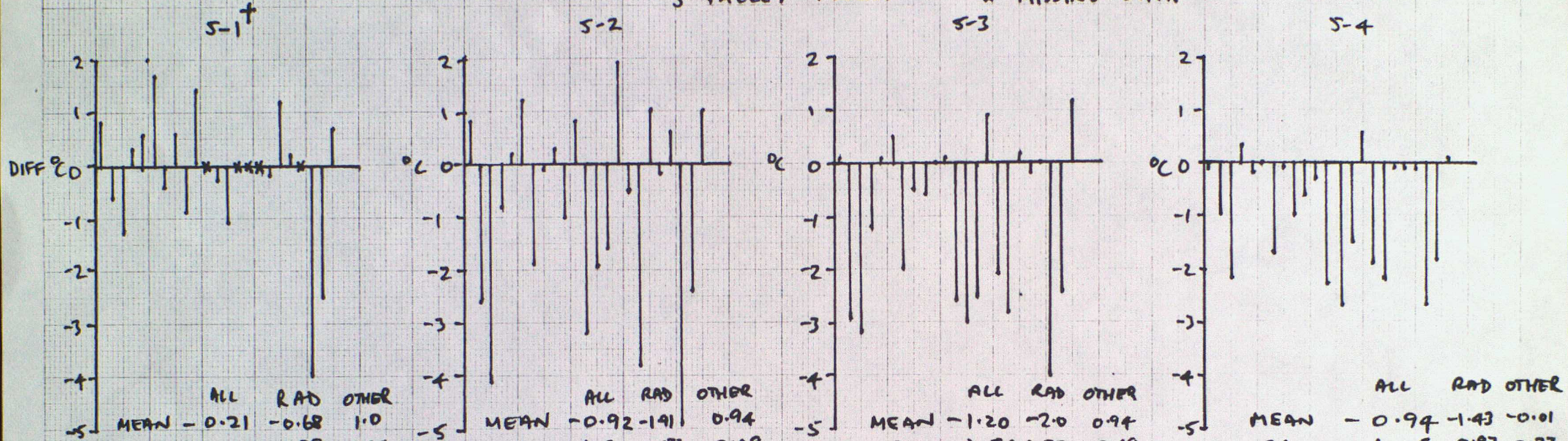
1b MINIMUM



DAILY GRASS MINIMUM DIFFERENCES BETWEEN VALLEY (REFERENCE) SITE AND OTHER SITES. FIG 2

ABOVE AXIS : VALLEY SITE WARMER

1 HILL SITE 2 UPPER SLOPE 3 MID-SLOPE 4 LOWER SLOPE
5 VALLEY FLOOR. x MISSING DATA



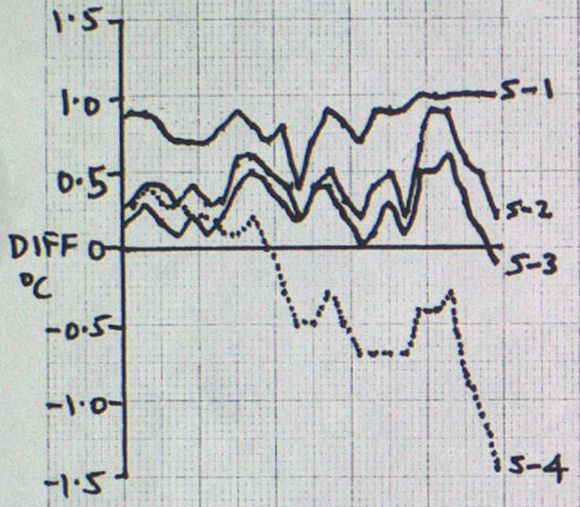
	5-1† ALL	5-1† RAD	5-1† OTHER	5-2 ALL	5-2 RAD	5-2 OTHER	5-3 ALL	5-3 RAD	5-3 OTHER	5-4 ALL	5-4 RAD	5-4 OTHER
MEAN	-0.21	-0.68	1.0	-0.92	-1.91	0.94	-1.20	-2.0	0.94	-0.94	-1.43	-0.01
SD	1.42	1.39	0.45	1.90	1.58	0.49	1.54	1.22	0.49	1.05	0.97	0.27

† VALUES SUSPECT DUE TO FAULTY THERMOMETER.

DAILY SOIL TEMPERATURE DIFFERENCES BETWEEN VALLEY (REFERENCE) SITE AND OTHER SITES FIG 3

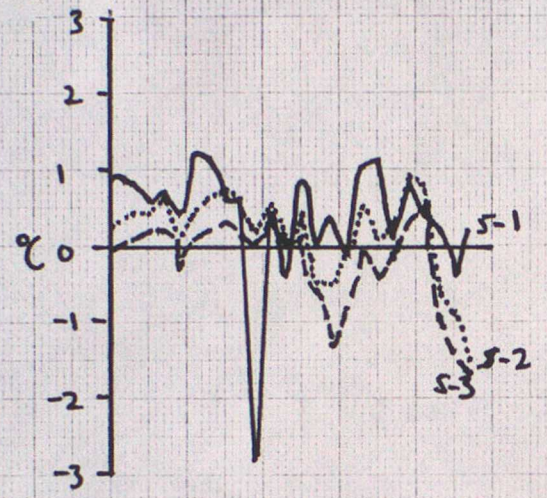
ABOVE AXIS: VALLEY SITE WARMER 1 HILL SITE 2 UPPER SLOPE 3 MID SLOPE 4 LOWER SLOPE 5 VALLEY FLOOR

30CM SOIL



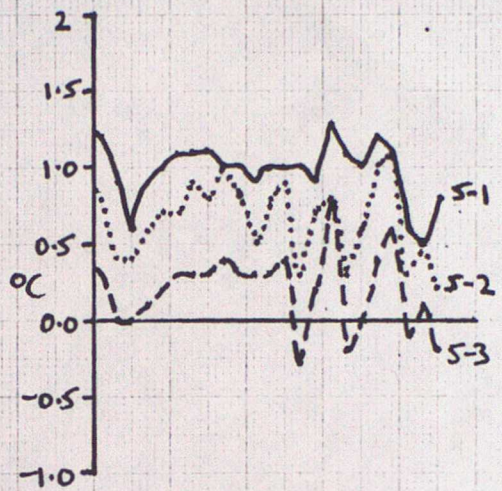
CASE	MEAN	SD
5-1	0·84	0·44
5-2	0·44	0·20
5-3	0·26	0·17
5-4	-0·29	0·49

10CM MAX



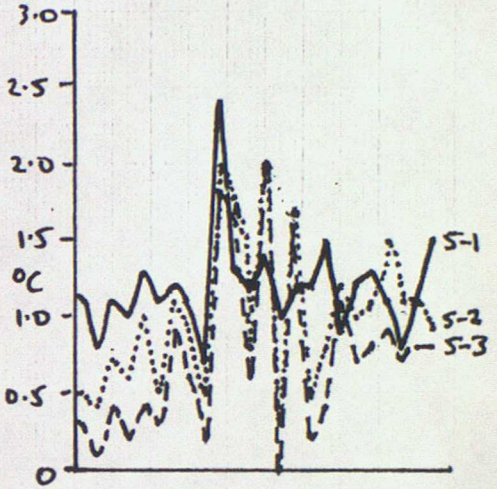
CASE	MEAN	SD
5-1	0·81	0·35
5-2	0·15	0·57
5-3	-0·21	0·61

10CM MIN



CASE	MEAN	SD
5-1	0·97	0·20
5-2	0·66	0·26
5-3	0·21	0·26

5CM SOIL



CASE	MEAN	SD
5-1	1·19	0·33
5-2	1·00	0·49
5-3	0·73	0·55